IV. OTHER ENVIRONMENTAL FACTORS

This chapter discusses some of the natural and anthropogenic factors that affect a wide variety of organisms in the bay system: freshwater inflows, wetland loss, water and sediment quality, and shrimp trawling. Only inflow was amenable to direct quantitative comparison with fisheries species (Chapter III). This study did not reveal unambiguous effects for any of these factors, other than that they affect the biota in complex ways and should not be neglected in questions of management.

Freshwater inflows

Inflows and the timing of inflows are undeniably important to the estuarine biota (Texas Department of Water Resources 1981, Mueller and Matthews 1987, Longley in review). High secondary productivity after floods has been observed repeatedly on the Texas coast (e.g. Johnson 1974, Flint and Rabalais 1981). Catch rates in 1991 were moderate to high in spite of possibly severe freshets during 1990 and 1991 (Figures 1A, 2A). The reasons for the importance of inflows are complex, however, and covary with other parameters, such as salinity, nutrients, and water levels.

The most obvious effect of freshwater inflow is the alteration of salinity regime. Johnson et al. (1981) observed that small fishes and crustaceans were more abundant in an upper Galveston Bay nursery area during wet years, and speculated that part of the value of nursery grounds derives from low salinities, which repulse larger fishes and thereby reduce intense predation. Oysters are a good example of an organism that is increasingly vulnerable to predation and parasitism as salinity approaches that of seawater, though prolonged freshets can be fatal.

Ward and Armstrong (1992) documented a decline in salinity in Galveston Bay over the last three decades. The decline is not clearly associated with changes in inflows. The authors speculate that salinity may have changed over time in the Gulf of Mexico, or the interaction between Gulf and estuarine waters may be less intense than in the past.

High inflows also cause high water levels in the estuarine system, therefore large areas of flooded marsh, and a greater area of nursery habitat accessible to organisms (Childers et al. 1990). Rainfall can deliver non-point source runoff and debris to the estuary (Newell et al. 1992), but theoretically heavy inflows can also cleanse the estuarine system by flushing pollutants. Perhaps the most important effect of freshwater inflow is the contribution of nutrients to estuarine waters. Nutrients support the phytoplankton that form the base of the estuarine food web; Lee (in prep.) suggested that nursery grounds are valuable to juvenile shrimp because of the abundant food in those areas (diatoms and polychaetes). Rivers are responsible for most of the long-term contribution of nutrients to estuaries, especially nitrogen and silica (Nixon 1981).

Unlike the weather, inflows can be managed to some degree. Most of the streams entering the Galveston Estuary have some form of flood control structure, of which Lake

Livingston on the Trinity River is the largest. It is hypothetically possible to stabilize the estuarine salinity regime at an optimum level, for example for oyster production. If flushing and nutrient input are important mechanisms, however, the energy of periodic floods may be necessary for efficient delivery. Too much stability may lead to a long-term decline in an organism upon which oysters depend, or an increase in the density of predators on oysters. Therefore it is important to maintain some variability in inflows.

The negative aspect of freshwater inflow is that low salinities and/or imbalanced nutrient inputs may contribute to noxious plankton blooms. The dinoflagellate bloom offshore of Galveston Island in 1984 was ascribed to low salinity by Harper and Guillen (1989). The bloom caused fish kills along the Gulf shoreline but did not enter the Galveston Estuary proper. The 1986-87 red tide (coincident with a mild El Niño event) was similarly associated with heavy rainfall by Trebatoski (1988). This bloom also affected the Gulf and estuaries to the south, but not the Galveston Estuary.

Wetland loss

The acreage of nursery habitat (seagrass beds and intertidal vegetation) is directly related to an area's productivity of certain fisheries species, of which penaeid shrimp are the best documented (e.g. Turner 1977, Turner and Brody 1983). The loss of tidal marsh in the Galveston Bay area (mainly from relative sea level rise, bulkheading, and from development and other land use changes) has progressed for several decades. From the 1950s to 1989 there was a net loss of about 19 percent (32,400 acres) of the estuary's vegetated wetlands (White et al. 1993), most of it before the mid-1970s. Seagrass beds, for example, were formerly widespread on the shores of Galveston and Trinity Bays. The submerged vegetation failed to reestablish after Hurricane Carla in 1961 (Pulich and White 1990), in part because of ongoing coastal subsidence. With the loss of the seagrass biome, nursery habitat for unknown quantities of estuarine organisms was also lost.

The CF data set shows declines for few of the fisheries species that depend on wetland vegetation for nursery habitat (e.g. brown shrimp, Atlantic croaker; Figures 1C, 1D, 2B, 2H). Declines ascribable to wetland loss are not conspicuous probably because the time series available postdates the period of most rapid wetland loss, and the former abundance of marsh-dependent species is unknown. In addition, the work of Zimmmerman et al. (1990, 1991) suggests that the absence of wholesale declines should be viewed with caution. Many fisheries species may benefit from the temporary increase in complexity and/or productivity of drowning marsh as relative sea level rises. However, if sea level continues to rise at a rate greater than marsh accretion, drowned marshes will be replaced by relatively unproductive open bay bottom and fisheries production will probably decline.

The contrast between bag seine and trawl data (Figures 1, 2 and 6, Chapter III) suggests bay margin habitats and the mid-bay are unalike in their productivity and response to environmental variables. However they are by no means uncoupled. The quantities of organic detritus generated in bay-margin marsh environments (Zimmerman et al. 1991) are probably important to mid-bay consumers (Texas Department of Water Resources 1981). A decline in productivity at the margins could have serious consequences for the entire bay.

A less ambiguous indicator of the state of wetlands are those birds that feed in them and require fairly extensive high-quality habitat. Chapter VII discusses the declining trends in wading birds that feed at the marsh-bay interface. This may be an early warning of a potentially serious problem at the bay margin.

Water and sediment quality

Water quality, specifically nutrient load and dissolved oxygen, has improved substantially since the 1970s (Oppenheimer et al. 1973, Stanley 1989, Ward and Armstrong 1992). However, the estuary continues to receive nutrients, heavy metals, unknown quantities of toxic organic compounds, and other pollutants, especially from urban areas (Newell et al. 1992, Cain 1993, Crocker 1993, Armstrong and Ward in press). King (1989) reported that concentrations of DDE, DDD, and chlordane in Galveston Bay fish tissues are below the national average, but that PCB levels are 1.5 times higher than average. Carr et al. (1993) found significant toxicity in sediments in 12 out of 24 sampled stations in the Galveston Estuary, especially those adjacent to dredged material disposal areas or produced water separator platforms. Polluted sites near the Houston Ship Channel are commonly reported (e.g. King et al. 1987, Carr et al. 1993), and the EPA's Environmental Monitoring and Assessment Program (EMAP) found high fish pathology rates in 1991 in East Bay Bayou (Summers and Hornig 1993). Fish kills caused by hypoxia or pollution may be less common than in past years but continue to occur.

In spite of these other findings, this study did not reveal any trends in living resources that could be directly related to pollution. Desbonnet et al. (1991) similarly found that finfish stocks correlate more closely with climate, fishing pressure, economics, and management than with water quality trends. Unfortunately, fishery-independent monitoring began in the 1970s, when pollution was more severe than it is now. Therefore it is unknown to what extent the observed population trends reflect recovery or a failure to recover. Furthermore there may be localized areas that are intolerably polluted but are too small to affect a bay-wide trend analysis. Future studies using Geographic Information System (GIS) technology may reveal some "hot spots". In addition, the decline in some species of birds that feed at the marsh-bay interface (Chapter VII) suggests there may be a problem at the bay margin, and contamination of water or sediments is one possible explanation. Petroleum and its products are especially likely to concentrate at the estuarine margin and to remain entrapped in marsh sediments (Kennish 1992).

It is difficult to interpret the implications of the study of ambient water quality in the Galveston Estuary by Ward and Armstrong (1992). The investigators found declines in salinity, turbidity, nitrates, and chlorophyll a over the past three decades. The declines in total suspended solids and turbidity may indicate the estuary's eventual return to a clearer, healthier state. Declining chlorophyll a and nitrate load are probably associated, because phytoplankton are probably nitrogen-limited in the Galveston Estuary (Buskey

1992). These trends probably indicate the success of efforts to improve waste water treatment and reduce pollution. On the other hand, these water quality trends may also indicate a present or eventual decline in primary productivity (from reduced nutrient loading, wetland loss, or other causes) that could cause an eventual decline in other species. The causes and implications of these water quality trends should be investigated more thoroughly to ensure that future management is applied appropriately.

Trawling

Several species are known to be vulnerable to shrimp trawling: Atlantic croaker, blue crab, pinfish, spot, sand seatrout, hardhead catfish, and Gulf menhaden (Bryan et al. 1982, Chai 1991, Nance et al. 1993). It is surprising that none of these "bycatch species" (with the exception of blue crab, Chapter VI) showed clear declining trends in this study or that of Osborn et al. (1992). Figures 1C, 1G, 1J, and 1P show declining trends for croaker, spot, menhaden, and catfish in bag seine catches, but the declines are uncorroborated by trawl data (2B, 2E, 2F, and 2I).

Nevertheless it is hard to imagine that intensive shrimp trawling has no effect on the benthos or on bottom-feeders. At least one apparent fish kill, dominated by Atlantic croaker, was probably the result of discarding by commercial shrimpers (Harper and Guillen 1989). All bay bottom is trawled that can legally and physically be trawled, possibly many times during a year. If future monitoring data for 1993 or 1994 show an increase in the "bycatch species", the recent regulation of shrimping should be investigated as a probable cause. If future monitoring reveals a long-term decline in these species, additional regulation should be considered. Devices that economically permit bycatch species to escape from shrimp trawls should be investigated and tested.